AD-A178 765 CONTROL OF LINEAR SYSTEMS OVER COMMUTATIVE NORMED ALGEBRAS WITH APPLICATI..(U) FLORIDA UNIV GAINESVILLE DEPT OF ELECTRICAL ENGINEERING E W KAMEN FEB 87 1/1

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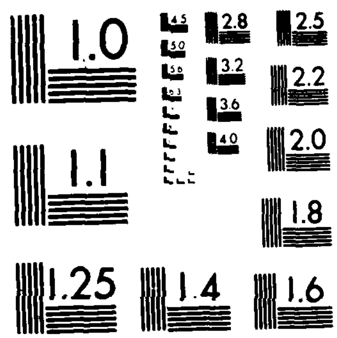

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The research centered on the development of a control theory for various classes of complex linear systems, including systems with time delays, systems with unknown parameters and time-varying systems. In the work on systems with time delays, we have been able to prove that stabilizable systems with one or more noncommensurate time delays can always be stabilized using a lumped(finite-dimensional) compensator. In many cases of interest such as delays in control or delays in measurements, we have developed

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) explicit constructive procedures for designing lumped compensators.

In the work on systems with unknown parameters, we have developed an indirect adaptive control scheme that does not require a persistent excitation to achieve global stability. The scheme is based on a new parameter estimation algorithm that forces the estimates of the unknown system parameters to converge to pre-specified intervals.

In the work on linear time-varying systems, we have developed a new approach to control based on a type of system augmentation. Via this approach, we have derived a number of results on the existence of canonical forms such as the control canonical form. We have also developed a "pole-placement" algorithm for time-varying systems.

ARO 20803.7-M

CONTROL OF LINEAR SYSTEMS OVER

COMMUTATIVE NORMED ALGEBRAS WITH APPLICATIONS

FINAL REPORT

BY

EDWARD W. KAMEN

FEBRUARY 1987

U. S. ARMY RESEARCH OFFICE

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UNIVERSITY OF FLORIDA

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1.0 Summary of Research Findings

The research centered on the development of a control theory for three major classes of complex linear systems: systems with time delays, systems with unknown parameters, and linear time-varying systems. A brief summary of the completed work is given below. A complete description of the work performed can be found in the list of papers and Ph.D. dissertations given in Section 2.0 of this report.

1.1 Systems with Time Delays

Output feedback control of a large class of linear systems with time delays was studied in terms of fractional representations of the transfer-function matrix. The entries of the fractional representation belong to an algebra of stable functions of a complex variable. The design of finite-dimensional stabilizing compensators is approached using a procedure for constructing proper rational approximations to functions analytic in the open right-half plane and continuous on the boundary of the one-point compactification of the closed right-half plane. An explicit construction is given for computing a Bezout fractional representation for a system consisting of a lumped system in cascade with a pure time delay. For details on this work see [1-3].

1.2 Systems with Unknown Parameters

The research on systems with unknown parameters has resulted in a new indirect adaptive control scheme for multi-input multi-output (MIMO) linear time-invariant discrete-time systems (see [4-7]). The scheme is based on a new parameter estimation algorithm that forces the estimates of the unknown system parameters to converge to pre-specified intervals. Using this property of the estimation algorithm, we have been able to prove global stability of the regulated system without requiring a persistent excitation. Simulations have shown that the adaptive scheme has good performance characteristics (see [5]).

1.3 Linear Time-Varying Systems

In one major phase of the work, we developed a notion of poles, zeros, and modes for the class of linear time-varying systems. These concepts are defined in terms of a noncommutative factorization of operator polynomials with time-varying coefficients. In the discrete-time case, it is shown that the poles can be computed by solving a nonlinear recursion with time-varying coefficients. In the continuous-time case, the poles can be calculated by solving a nonlinear differential equation with time-varying coefficients. The theory is applied to the study of the zero-input response and asymptotic stability. It is shown that if a time-varying analogue of the Vandermonde matrix is invertible, the zero-input response can be decomposed into a sum of modes associated with the poles. Stability is then studied in terms of the components of the modal decomposition. For details, see [8].

In the second part of the work, an algebraic approach based on "augmentation" was developed for linear discrete-time time-varying systems. Using this approach, it is shown how to design feedback control systems for a broad class of time-varying systems which result in a closed-loop system matrix that is equivalent to a constant matrix with arbitrary assignable eigenvalues. The theory yields controllers having a much lower order in general than that obtained in past work. We were also able to define a discrete-time time-varying version of Sylvester's resultant matrix. This definition can be used to check coprimeness of polynomials and polynomial matrices with time-varying coefficients, to examine reachability of a given system, and to design compensators which result in a type of assignability. For details, see [9-10].

2.0 Papers and Dissertations Prepared Under ARO Contract DAAG29-84-K-0081 (July 1, 1984 - June 30, 1986).

[1] E. W. Kamen, P. P. Khargonekar, and A. Tannenbaum, "Stabilization of time-Delay Systems Using Finite-Dimensional Compensators," **IEEE Transactions on Automatic Control**, Vol. AC-30, pp. 75-78, January 1985.

[2] E. W. Kamen, P. P. Khargonekar, and A. Tannenbaum, "New Techniques for the Control of Linear Infinite-Dimensional Systems," in **Frequency Domain and State Space Methods for Linear Systems**, C. I. Byrnes and A. Lindquist, Eds., North-Holland, Amsterdam, pp. 355-365.

[3] E. W. Kamen, P. P. Khargonekar, and A. Tannenbaum, "Proper Stable Bezout Factorizations and Feedback Control of Linear Time-Delay Systems," **International J. Control**, Vol. 43, pp. 837-857, 1986.

[4] K. Ossman and E. W. Kamen, "An Adaptive LQ Controller for MIMO Linear Time-Invariant Discrete-Time Systems," in **Proc. 24th Conference on Decision and Control**, Ft. Lauderdale, FL, pp. 843-844, December 1985.

[5] K. Ossman, "New Results in Indirect Adaptive Control," Ph.D. Dissertation, University of Florida, Gainesville, FL, August,1986.

[6] K. Ossman and E. W. Kamen, "A Parameter Estimator with Convergence to Prespecified Intervals for Discrete-Time Systems," in **Proc. 1986 American Control Conference**, Seattle, WA, June 1986.

[7] K. Ossman and E. W. Kamen, "Adaptive Regulation of MIMO Linear Discrete-Time Systems without Requiring a Persistent Excitation," **IEEE Transactions on Automatic Control**, Vol. AC-32, 1987 (to appear).

[8] E. W. Kamen, "The Poles and Zeros of a Linear Time-Varying System," submitted to **Linear Algebra and Its Applications**, July 1986.

[9] S. K. Hwang, "An Augmentation Approach and Theory of the Resultant for Linear Time-Varying Systems," Ph.D. Dissertation, University of Florida, Gainesville, FL, December 1986.

[10] S. K. Hwang and E. W. Kamen, "Feedback Control of Augmented Multivariable Linear Time-Varying Systems," in preparation.

3.0 Scientific Personnel Supported on Contract

E. W. Kamen, Principal Investigator
S. K. Hwang, Predoctoral Student (Awarded Ph.D. in December 1986)
K. A. Ossman, Predoctoral Student (Awarded Ph.D. in August 1986).

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